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DESCRIPTION

METHOD AND DEVICE FOR PRODUCTION OF METAL SLURRY, AND METHOD AND DEVICE FOR PRODUCTION OF INGOT

Technical Field:

This invention relates to a method and a device for the production of metal slurry in a partly molten (partly solidified) state allowing the coexistence of a metal in a molten state (liquid phase) and a metal in a solidified state (solid phase), and a method and a device for the production of an ingot from the partly molten (partly solidified) metal slurry.

Background Art:

Generally, as casting methods which utilize rheology and thixotropy of a partly molten and partly solidified metal, namely the quality of low viscosity and excellent fluidity, the rheocast method (partly solidified casting method) resorting to the former property and the thixocasting method (partly molten casting method) resorting to the latter property have been known.

These casting methods invariably perform casting by using metal slurry in a partly molten and partly solidified state allowing the coexistence of a molten liquid-phase metal and a solid-phase metal.

The cast structures of the ingot produced by the casting methods described above, the cast magnesium alloy and other various metals and alloys are preferred to be wholly in the form of very small spheres because they are required to avoid revealing directionality of crystal, excel in various mechanical properties and suppress segregation of components.

With the object of grain-refining and spheroidizing the cast structure, a molten metal, for example, is poured onto a tilted cooling body and cooled by this tilted cooling body or the molten metal is added with a grain refining agent and subjected to electromagnetic stirring or mechanical stirring (refer, for example, to JP-A 2001-252759 and JP-A HEI 10-128516).

When the molten metal is poured onto the tilted cooling body and consequently cooled by the tilted cooling body, however, since this molten metal is suddenly cooled on the surface of the tilted cooling body, the solidification of the resultant metal slurry often occurs on the tilted cooling body, with the possible result that the metal slurry will be prevented from being produced continuously.

Particularly, when the molten metal is formed of a magnesium alloy, it encounters difficulty in continuously producing metal slurry under the existing circumstances because the magnesium alloy readily solidifies owing to its small latent heat of solidification.

When the molten metal is enabled by the addition of a grain refining agent to give rise to crystals in the form of very small spheres, this procedure is not applicable to all the metals but is applicable to aluminum alloys and magnesium alloys exclusively and it further requires the amount of the grain refining agent to be added and the temperature of addition to be exactly controlled and moreover imposes a limit on the time of retention of the grain-refined state of crystals subsequent to the addition of the grain refining agent.

When the molten metal is subjected to an electromagnetic stirring or a mechanical stirring, this procedure entails an addition to the device and an increase in the cost of energy.

This invention, therefore, is aimed at providing a method and a device for the production of metal slurry ideally and continuously by using a tilted cooling body.

This invention is also aimed at providing a method and a device for the production of metal slurry ideally and continuously even when the molten metal is formed of a magnesium alloy.

This invention is further aimed at providing a method and a device for the production of metal slurry at a suppressed energy cost without enlarging the device as compared with a device of mechanical stirring or a device of electric stirring.

Disclosure of the Invention:

This invention provides a method for the production of metal slurry, comprising pouring a molten metal onto a tilted cooling body and allowing the molten metal to cool on the tilted cooling body, wherein vibration is imparted to the tilted cooling body.

This invention further provides a method for the production of metal slurry, comprising pouring a molten metal onto a vibrating cooling body and causing the vibrating cooling body to cool the molten metal.

In each of the methods for the production of metal slurry, the molten metal is formed of a magnesium alloy.

This invention also provides a device for the production of metal slurry, comprising a tilted cooling body onto which a molten metal is poured and which is equipped with a tilted cooling body vibrating mechanism for imparting vibration to the tilted cooling body.

This invention further provides a device for the production of metal slurry, comprising a cooling body onto which a molten metal is poured to cool the molten metal and which is equipped with a cooling body vibrating mechanism for imparting vibration to the cooling body.

In each of the devices for the production of metal slurry, the molten metal is formed of a magnesium alloy.

This invention also provides a method for the production of an ingot, comprising supplying a mold with a molten metal and cooling the molten metal by cooling the mold, wherein vibration is imparted to the mold.

This invention also provides a method for the production of an ingot, comprising pouring a molten metal onto a vibrating cooling body to cool the molten metal with the vibrating cooling body, supplying the cooled molten metal to a mold and further cooling the cooled molten metal by cooling the mold.

In each of the methods for the production of an ingot, the molten metal is formed of a magnesium alloy.

This invention also provides a device for the production of an ingot, comprising a mold to which a molten metal is supplied and which is cooled and equipped with a mold vibrating mechanism for imparting vibration to the mold.

This invention further provides a device for the production of an ingot, comprising a cooling body onto which a molten metal is poured for cooling the molten metal, a mold to which the cooled molten metal is supplied and which is cooled to further cool the

cooled molten metal and a cooling body vibrating mechanism for imparting vibration to the cooling body.

In each of the devices for the production of an ingot, the molten metal is formed of a magnesium alloy.

According to the method and the device for the production of a metal slurry contemplated by this invention, since a tilted cooling body vibrating mechanism is provided for the purpose of preventing a molten metal from being solidified on a tilted cooling body or the tilted cooling body vibrating mechanism is provided for the purpose of causing crystals forming on a surface of the tilted cooling body to be forcibly liberated and flowed down during an initial stage of formation of crystals or preventing the molten metal from being solidified on the cooling body in order that the crystals forming on the surface of the cooling body may be forcibly liberated and flowed down during the initial state of the formation of the crystals, the metal slurry possessing crystals of a form of very small spheres can be efficiently and continuously produced without enlarging the device as compared with the device of mechanical stirring or electromagnetic stirring or without increasing a cost of energy, and the produced metal slurry can be enabled to possess crystals of the form of smaller spheres than the metal slurry obtained by the conventional procedure which contemplates no impartation of vibration to the tilted cooling body.

Since the molten metal is formed of a magnesium alloy, when the metal slurry is cast in its original form of globular crystals, the time for finishing the produced casting can be shortened and the number of casting steps can be decreased.

According to the method and the device for the production of an ingot contemplated by this invention, since a mold vibrating mechanism is provided for the purpose of preventing a molten metal from adhering to and solidified in the mold and causing crystals forming on the inner surface of the mold to be forcibly liberated during the initial stage of the formation of the crystals or a cooling body vibrating mechanism is provided for the purpose of preventing the molten metal from adhering to and solidified on the cooling body and causing crystals forming on the surface of the cooling body to be forcibly liberated and flowed down during the initial stage of the formation of the crystals, the cast structure of a varying kind of metal can be reduced to wholly smaller spheres than

the cast structure obtained by the conventional procedure which contemplates no impartation of vibration to the mold without enlarging the device as compared with the device for mechanical stirring or electromagnetic stirring or increasing the cost of energy.

Even from a magnesium alloy which possesses a particularly small latent heat of solidification and therefore readily solidifies and renders difficult the production of metal slurry in a partly molten state, this invention can easily produce manganese alloy slurry.

Brief Description of the Drawings:

Fig. 1 is an explanatory diagram schematically illustrating the construction of a device for continuous production of a cast bar by the application of the first embodiment of the device for the production of metal slurry according to this invention.

Fig. 2 is a copy of an optical micrograph illustrating the solidified structure resulting from reheating and solidifying a continuous cast bar produced by the conventional device for the production of a continuous cast bar.

Fig. 3 is a copy of an optical micrograph illustrating the solidified structure resulting from reheating and solidifying a continuous cast bar produced by the device for the production of a continuous cast bar shown in Fig. 1.

Fig. 4 is a cross section schematically illustrating the construction of the second embodiment of the device for the production of an ingot contemplated by this invention.

Fig. 5 is a plan view schematically illustrating the construction of a mold conveying mechanism for the device for the production of the ingot shown in Fig. 4.

Fig. 6 is a copy of an optical micrograph illustrating the solidified structure resulting from reheating and solidifying an ingot produced by the conventional device for the production of an ingot.

Fig. 7 is a copy of an optical micrograph illustrating the solidified structure resulting from reheating and solidifying an ingot produced by the device for the production of an ingot according to the second embodiment of this invention.

Fig. 8 is a partial cross section schematically illustrating the construction of the third embodiment of the device for the production of an ingot contemplated by this invention.

Fig. 9 is a cross section schematically illustrating the construction of another example of the melting furnace to be used in the device for the production of a continuous cast bar or the device for the production of an ingot.

Best Mode for carrying out the Invention:

This invention will be described more specifically below with reference to the accompanying drawings.

Referring to Fig. 1, an device I for the production of a continuous cast bar comprises a melting furnace 11 for melting metals and producing a molten magnesium alloy (molten metal M), a melting furnace temperature adjusting mechanism 17 for adjusting the melting furnace 11 to a required melting temperature, a molten metal discharge controlling mechanism 21 for controlling the amount of the molten metal M to be discharged from the melting furnace 11, a tilted cooling body 31 for cooling the molten metal M discharged from the melting furnace 11 and poured to the upper part thereof till metal slurry U in a partly molten state, a tilted cooling body vibrating mechanism 36 for imparting vibration to the tilted cooling body 31, a cylindrical mold 41 supplied with the metal slurry from the tilted cooling body 31, a mold cooling mechanism 51 for cooling the mold 41, a refrigerant cooling mechanism 61 for cooling a refrigerant 53 for the mold cooling mechanism 51, a feed roller mechanism 71 for drawing a continuous cast bar B from the mold 41 at a required casting speed, and a cutting mechanism 81 for cutting the continuous cast bar B fed out by the feed roller mechanism 71 into billets L of a prescribed length.

Incidentally, a device S for the production of metal slurry comprises the melting furnace 11 through the tilted cooling body vibrating mechanism 36.

The melting furnace 11 comprises a main body 12 of the melting furnace opened in the upper end, a delivery tube 13 fitted in an airtight manner through the bottom of the main body 12 and so disposed as to have the upper terminal thereof fall at a prescribed position inside the main body 12, a heater 14 embedded in the main body 12, and a lid 15 for blocking the upper part of the main body 12.

Then, the main body 12 of the melting furnace is provided on the bottom thereof with a dross vent 16 for release of a sedimented impurity, such as dross.

The melting furnace temperature adjusting mechanism 17 comprises a thermocouple 18 as an instrument for measuring the temperature in the melting furnace 11 and an electrification controlling part 19 for starting supply of electric power to the heater 14 to enable the temperature detected by the thermocouple 18 to reach the preset melting temperature and stopping the supply of the electric power to the heater 14.

Incidentally, the temperature in the melting furnace 11 is set by the melting furnace temperature adjusting mechanism 17 at a level not lower than the liquid phase temperature of the magnesium alloy so as to produce the molten metal M of the magnesium alloy.

The molten metal delivery controlling mechanism 21 comprises a heater-embedded control bar 22 inserted through an insertion hole 15a formed in the lid 15 of the melting furnace 11 and a control bar driving part 23 for inserting the heater-embedded control bar 22 into the melting furnace 11 and delivering the molten metal M from the delivery tube 13.

The tilted cooling body 31 is installed at an elevation angle in the range of 20 degrees to 80 degrees and is set at a constant temperature by a water-cooled or air-cooled tilted cooling body cooling mechanism which is omitted from illustration herein.

The molten metal M flowing down on the tilted cooling body 31, therefore, has the temperature thereof lowered during the course of the flow.

That is, the temperature of the magnesium alloy on the tilted cooling body 31 falls at a level not higher than the liquidus temperature of a magnesium alloy and not lower than the solidus temperature of the magnesium alloy.

The reason for setting the temperature of the molten magnesium alloy flowing down on the tilted cooling body 31 below the liquidus temperature of the magnesium alloy and above the solidus temperature of the magnesium alloy is that the spheroidal crystals formed when the molten metal M is cooled are enabled to retain the form of slurry in a partly molten state without being dissolved, dissipated or completely solidified.

The tilted cooling body vibrating mechanism 36 comprises an eccentric shaft and a motor, for example, and is intended to impart vibration to the tilted cooling body 3 in

order that the solidified shell of the molten metal M adhering to the tilted cooling body 31 may be forcibly liberated during the initial stage of the formation thereof.

The mold 41 comprises a main body 42 of the mold in the shape of a cylinder opened at both the terminals and a flange part 43 disposed on the outer periphery of one (upper) terminal of the main body 42 of the mold.

Then, the mold 41 is retained by a mold retaining unit 46 which, in a state transfixed with the main body 42 of the mold, allows the flange part 43 to engage the upper terminal thereof.

The mold cooling mechanism 51 comprises a cooling bath 52 having the bottom thereof transfixed with the main body 42 of the mold 41 in a watertight manner and a refrigerant 53 contained in the cooling bath 52.

The refrigerant cooling mechanism 61 comprises a piping 62 having both the terminals thereof connected to the cooling bath 52, a refrigerant cooling part 63 disposed halfway along the length of the piping 62, and a pump 64 disposed halfway along the length of the piping 62 and adapted to circulate the refrigerant 53 in the cooling bath 52.

Incidentally, the refrigerant 53 is set by the refrigerant cooling mechanism 62 at a constant temperature for solidifying the metal slurry U in the partly molten state such as, for example, at a level of not higher than the solidus temperature of the magnesium alloy.

The feed roller mechanism 71 comprises a pair of rollers 72 for nipping and drawing the continuous cast bar B emanating from the mold 41 and a rotary drive part (73) not shown that is adapted to rotate at least one of the pair of rollers 72 at an expected casting speed.

The cutting mechanism 81 comprises a cutting blade 82 for cutting the continuous cast bar B delivered by the feed roller mechanism 71 into billets L of a prescribed length, a motor 83 for rotating the cutting blade 82, and a mobile driving part (84) not shown that is adapted to move the motor 83 in the horizontal direction.

The production of the continuous cast bar B and the billet L will be described below.

After the main body 12 of the melting furnace has been charged with necessary metals and then closed with the lid 15, the molten metal M of magnesium alloy is formed

by heating the main body 12 of the melting furnace with the heater 14, thereby melting the metals.

Then, by driving the heater-embedded control bar 22 downwardly with the control bar driving part 23, the molten metal M is successively delivered from the delivery tube 13 onto the tilted cooling body 31.

Since the magnesium alloy has the smallest specific gravity in all the practical metals when the molten metal M is delivered in this manner, most impurities and compounds sediment to the bottom of the main body 12 of the melting furnace. By extracting the supernatant of the molten metal M, therefore, it is made possible to supply the molten metal M deprived of substantially all the impurities and compounds to the upper part of the tilted cooling body 31.

The impurities which sediment to the bottom of the main body 12 of the melting furnace are called "dross." Inclusion of this dross prevents the produced magnesium alloy from becoming clean and suffers it to become a rejected product. Thus, the amount of the molten metal M that can be expelled by lowering the heater-embedded control bar 22 is preferred to be 70% to 80% of the interior volume of the main body 12 of the melting furnace from the side lower than the upper end of the delivery tube 13.

The dross which has sedimented to the bottom of the main body 12 of the melting furnace is only required to be expelled by properly manipulating the dross vent 16.

The molten metal M delivered onto the tilted cooling body 31 as described above is cooled by contact with the surface of the tilted cooling body 31 and consequently crystallized partly and converted into the partly melted and partly solidified metal slurry U and eventually supplied as such to the mold 41.

Since the tilted cooling body 31 is being vibrated at this time by the tilted cooling body vibrating mechanism 36, the solidified shell, if suffered to adhere to the tilted cooling body 31, is forcibly liberated in the form of small spheres during the initial stage of the formation thereof and consequently spheroidized.

The metal slurry U which has been supplied into the mold 1 is cooled with the mold cooling mechanism 51 and is then cast into the continuous cast bar B by the use of a dummy bar.

The continuous cast bar B produced in this manner is conveyed by the feed roller mechanism 71 and cut by the cutting mechanism 81 into billets L of a prescribed length.

These billets L are used as in forging or extrusion or, as occasion demands, are heated by a partly melting work till they acquire a partly molten state.

The solidified structure observed under an optical microscope of a billet which was produced by a continuous cast bar producing device devoid of a tilted cooling body vibrating mechanism and subsequently reheated and solidified is illustrated in Fig. 2 and the solidified structure observed under an optical microscope of a billet which was produced by the continuous cast bar producing device I of the first embodiment of this invention and subsequently reheated and solidified is illustrated in Fig. 3.

The solidified structure of the billet produced by the continuous cast bar producing device devoid of the tilted cooling body vibrating mechanism, as seen from Fig. 2, was formed of spheroidized crystals grown to a size of no less than several hundreds of μm.

The solidified structure of the billet produced by the continuous cast bar producing device 1 of the first embodiment of this invention, as seen from Fig. 3, was formed of fine spherical crystals measuring 10 μm to 200 μm in diameter.

According to the metal slurry producing device S of the first embodiment of this invention, since the tilted cooling body vibrating mechanism 36 is provided for the purpose of preventing the molten metal M from being solidified on the tilted cooling body 31 and since the crystals formed on the surface of the tilted cooling body 31are forcibly liberated and flowed down during the initial state of their formation as described above, the metal slurry U comprising fine spherical crystals such as, for example, spherical crystals measuring 10 μm to 200 μm can be efficiently and continuously produced without enlarging the device in use as compared with the device of mechanical stirring or electromagnetic stirring or without adding to the cost of energy, and the metal slurry U comprising finer spherical crystals can be obtained than by the conventional procedure avoiding impartation of vibration to the tilted cooling body.

Since the molten metal M is formed of a magnesium alloy, the billets L comprising fine spherical crystals can be produced. When the billets L are forged or cast in a partly molten state, the finishing time can be shortened and the number of steps of the finishing

work can be decreased. When the metal slurry U is cast in the original form of spherical crystals, the time for finishing the casting can be shortened and the number of steps of the finishing work can be decreased.

Fig. 4 is an explanatory diagram equivalent to a side section illustrating the schematic structure of an ingot producing device of the second embodiment of this invention and Fig. 5 is an explanatory diagram equivalent to a plan view illustrating the schematic structure of the mold conveying mechanism in the ingot producing device of the second embodiment of this invention.

Incidentally, Fig. 4 is equivalent to a cross section taken through Fig. 5 along line A-A.

In Fig. 4 or Fig. 5, an ingot producing device P comprises a melting furnace 111 for melting metals and forming a molten magnesium alloy (molten metal M), a melting furnace temperature adjusting mechanism 117 for adjusting the melting furnace 111 to a necessary melting temperature, a molten metal delivery controlling mechanism 121 for controlling the amount of the molten metal M delivered from the melting furnace 111, a mold 131 to which the molten metal M from the melting furnace 111 is supplied, a mold conveying mechanism 141 for conveying the mold 131, a mold cooling mechanism 151 for cooling the mold 131 conveyed by the mold conveying mechanism 141, a mold cooling refrigerant cooling mechanism 161 for cooling a refrigerant 153 for the mold cooling mechanism 151, and a mold vibrating mechanism 171 for imparting vibration to the mold 131 conveyed by the mold conveying mechanism 141 from the melting furnace 111 to the position Pa for supply of the molten metal M (position of vibration).

The melting furnace 111 comprises a main body 112 of the melting furnace opened in the upper part, a delivery tube 113 mounted in a watertight manner as transfixed to the bottom of the main body 112 of the melting furnace and having the upper terminal thereof set at the prescribed position inside the main body 112 of the melting furnace, a heater 114 embedded in the main body 112 of the melting furnace, and a lid 115 for blocking the upper part of the main body 112 of the melting furnace.

Then, the main body 112 of the melting furnace is provided on the bottom thereof with a dross vent 116 for withdrawing dross, for example.

The melting furnace temperature controlling mechanism 117 comprises a thermocouple 118 as a temperature measuring unit for measuring the temperature in the melting furnace 111 and an electrification controlling part 119 for starting supply of electric power to the heater 114 so as to enable the temperature detected by the thermocouple 118 to reach the present melting temperature or stopping the supply of the electric power to the heater 114.

The temperature in the melting furnace 111 is set by the melting furnace temperature adjusting mechanism 117 at the level of not lower than the liquidus temperature of the magnesium alloy for the purpose of forming the molten metal M of the magnesium alloy.

The molten metal delivery controlling mechanism 121 comprises a heater-embedded control bar 122 inserted into an insertion hole 115a formed in the lid 115 of the melting furnace 111 and a control bar driving part 123 for inserting the heater-embedded control bar 122 into the melting furnace 111 and consequently expelling the molten metal M from the delivery tube 113.

The mold 131 comprises a cylindrical main body 132 of the mold opened at one terminal (upper terminal) and a flange part 133 disposed on the outer periphery of the one terminal (upper terminal) of the main body 132 of the mold.

The mold conveying mechanism 141 comprises a mold retaining part 142 which, in a state transfixed with the main body 132 of the mold, enables the flange part 133 to be detachably fixed at the upper terminal thereof, a conveyor 143 for conveying a plurality, eight in the present example, of mold retaining parts 142 as spaced in an elliptical course, a driving toothed wheel 144 and a driven toothed wheel 145 for forwarding the conveyor 143 in an elliptical course, and a conveyance driving part (146) not shown that is adapted to repeat an operation of driving the driving toothed wheel 144 over a prescribed distance clockwise in the bearings of Fig. 5, for example, and stop it for a prescribed duration.

Incidentally, in Fig. 5, Ps denotes a mold mounting position for mounting the mold 131 to the mold retaining part 142 which is forwarded by the conveyor 143, Pa denotes a molten metal supplying position for supplying the molten metal M from the melting furnace 111 to the mold 131 advanced on the conveyor 143 or a vibrating position for

imparting vibration with the mold vibrating mechanism 171 to the mold 131 advanced on the conveyor 143, and Po denotes a mold demounting position for demounting the mold 131 from the mold retaining part 142 forwarded on the conveyor 143.

The mold cooling mechanism 151 comprises a cooling bath 152 through which the mold 131 conveyed by the mold conveying mechanism 141 passes and the refrigerant 153 contained in this cooling bath 152.

The cooling bath 152 is elliptically formed as illustrated in Fig. 5 and enabled to contain the refrigerant 153 between the partition wall 152a formed at the upstream position from the mold mounting position Ps and the partition wall 152b formed at the downstream position from the mold demounting position Po.

The mold cooling refrigerant cooling mechanism 161 comprises a piping 162 having the opposite terminals thereof connected to the cooling bath 152, a refrigerant cooling part 163 disposed halfway along the length of the piping 162, and a pump 164 disposed halfway along the length of the piping 162 and adapted to circulating the refrigerant 153 inside the cooling bath 152.

Incidentally, the refrigerant 153 is set by the mold cooling refrigerant cooling mechanism 161 at a constant temperature for solidifying the molten metal M such as, for example, the level not higher than the solidus temperature of the magnesium alloy.

The reason for setting the temperature of the refrigerant 153 at a level of not higher than the solidus temperature of the magnesium alloy is that the crystals formed on the inner surface of the main body 132 of the mold are enabled to be liberated by the vibration of the main body 132 of the mold and consequently transformed into a partly solidified state or to a solidified state.

The mold vibrating mechanism 171 comprises a transmitting member 172 provided with a notch 172a for holding the flange part 133 of the mold 131, a vibrating part 173 mounted on the right side upper surface of the transmitting member 172 and comprising an eccentric shaft and a motor, for example, and a transmitting member moving drive part (174) not shown that is adapted to allow movement of the transmitting member 172 between the retired position (the position indicated with a solid line in Fig. 4 and Fig. 5) in which the mold 131 can be conveyed by the mold conveying mechanism

141 without requiring the flange part 133 to be held in the notch 172a and the advanced position (the position indicated with a two-dot chain line in Fig. 4 and Fig. 5) at which the flange part 133 is held in the notch 172a.

Now, the production of the ingot N will be described below.

First, the molten metal M of a magnesium alloy is formed by charging the main body 112 of the melting furnace in the state illustrated in Fig. 4 with necessary metals, closing the main body 112 of the melting furnace with the lid 115, and heating the main body 112 of the melting furnace with the heater 114, thereby melting the metals.

By actuating the mold conveying mechanism 141, the conveyor 143 is moved and the molds 131 are retained by the mold retaining parts 142 successively conveyed to the mold mounting position Ps, and the main bodies 132 of the molds are partly embedded in the refrigerant 153 of the cooling bath 152.

When the mold 131 mounted on the mold retaining part 142 as described above and advanced by the conveyor 143 to the molten metal supplying position (vibrating position) Pa and brought to a stop at that position, the transmitting member moving drive part (174) not shown advances the transmitting member 172 and causes the flange part 133 of the mold 131 to be contained in the notch 172a and the vibrating part 173 is actuated as well to impart vibration to the mold 131.

Then, by driving and descending the heater-embedded control bar 122 with the control bar driving part 123, the molten metal M is enabled to be delivered in a prescribed amount from the delivery tube 113 into the mold 131.

When the molten metal M is delivered in this manner, the amount of the molten metal M that can be delivered by lowering the heater-embedded control bar 122 is preferred to be in the range of 70% to 80% of the volume of the main body 112 of the melting furnace below the upper terminal of the delivery tube 113 in order that the magnesium alloy clean by not including dross may be delivered.

Then, the dross which has sedimented to the bottom of the main body 112 of the melting furnace may be discharged by properly manipulating the dross vent 116.

The molten metal M delivered in the prescribed amount into the main body 132 of the mold as described above is cooled by contacting the inner surface of the main body

132 of the mold and consequently crystallized and spheroidized and caused to adhere to the inner surface of the main body 132 of the mold.

Since the mold 131 is vibrated by the mold vibrating mechanism 171, the spherical crystals are grown and forcibly liberated from the inner surface of the main body 132 of the mold and successively sedimented to the bottom of the main body 132 of the mold and turned into the ingot N.

When the mold 131 placed at the molten metal delivering position (vibrating position) Pa has been vibrated for a prescribed duration such as, for example, in the approximate range of 1 minute to 5 minutes, the vibrating part 173 is stopped and the transmitting member 172 is retracted with the transmitting member moving driving part (174) not shown.

Then, the mold conveying mechanism 141 repeats an operation of conveying the mold 131 supplied with the molten metal M to a prescribed distance toward the mold demounting position Po, conveying the next mold 131 to the molten metal supplying position (vibrating position) Pa, and supplying the molten metal M from the melting furnace 111 as kept vibrated as described above to the mold 131 conveyed to the molten metal supplying position (vibrating position) Pa.

Since the mold 131 which has been conveyed to the mold demounting position Po has the metal slurry U initially held in a partly solidified state already solidified into the ingot N, it is removed from the mold retaining part 142, reversed to expel the ingot N, and given a cleaning of the interior thereof in preparation for next use.

The solidified structure observed under an optical microscope of an ingot produced by the ingot producing device devoid of a mold vibrating mechanism and reheated and solidified is shown in Fig. 6 and the solidified structure observed under an optical microscope of an ingot N produced by the ingot producing deice P of the second embodiment of this invention and reheated and solidified is illustrated in Fig. 7.

The solidified structure of the ingot produced by the ingot producing device devoice of a mold vibrating mechanism, as noted from Fig. 6, has crystals grown to a size exceeding several hundreds of μm.

However, the solidified structure of the ingot N produced by the ingot producing device P of the second embodiment of this invention, as noted from Fig. 7, has fine spherical crystals in the range of 10 μm to 200 μm.

According to the ingot producing device P of the second embodiment of this invention, since the mold vibrating mechanism 171 is provided for the purpose of preventing the molten metal M from solidifying as adhering to the mold 131 and the crystals formed on the inner surface of the mold 13` is forcibly liberated during the initial state of formation thereof, the cast structure of a varying kind of metal can be formed in wholly finer spheres measuring 10 μm to 200 μm, for example, than the conventional procedure avoiding imparting vibration to the mold without enlarging the device in use as compared with the device of mechanical stirring or the device of electromagnetic stirring or without increasing the cost of energy.

Since the molten metal M is formed of a magnesium alloy, it is enabled to shorten the time for finishing the ingot N and decrease the number of steps of the finishing process.

Fig. 8 is an explanatory diagram equivalent to a partial lateral section illustrating schematically the structure of the ingot producing device as the third embodiment of this invention and the parts identical or equivalent to those found in Fig. 4 and Fig. 5 are denoted by the like reference numerals and will be omitted from the description.

Referring to Fig. 8, the ingot producing device P comprises a melting furnace (111) for melting metals and forming a molten metal M of a magnesium alloy, a melting furnace temperature adjusting mechanism (117) for adjusting the melting furnace (111) to a necessary melting temperature, a molten metal delivery controlling mechanism (121) for controlling the amount of the molten metal M delivered from the melting furnace (111), a mold 131 for receiving the molten metal M supplied from the melting furnace (111), a mold conveying mechanism 141 for conveying the mold 131, a mold cooling mechanism (151) for cooling the mold 131 conveyed by the mold conveying mechanism 141, a mold cooling refrigerant cooling mechanism (161) for cooling the refrigerant (153) for the mold cooling mechanism (151), a cooling body 211 of a hemispheric shape, for example, inserted into the mold 131 placed at the molten metal supplying position (vibrating position) (Pa) and adapted to admit the pour therein of the molten metal M, a cooling body

vibrating mechanism 221 for imparting vibration to the cooling body 211, and a cooling body cooling mechanism 231 for cooling the cooling body 211.

The melting furnace (111) to the mold cooling refrigerant cooling mechanism (161), though omitted from illustration, are constructed in the same manner as in the second embodiment.

The cooling body vibrating mechanism 221 comprises two pipes 222 bent like a crank, closed at one terminal (right terminal), fixed at the other terminal, enabled the other terminal (left terminal) to support the cooling body 211, an vibrating part 223 for imparting vibration from below, for example, to at least one of the pipes 222, and the cooling body moving driving part (224) not shown that is moved, with one terminal (right terminal) as the fulcrum, between the vibrating position (descending position) (the position shown in Fig. 8) at which the cooling body 211 is placed inside the mold 123 (descended position) (the position shown in Fig. 8) and the non-vibrating position (ascended position) at which the cooling body 211 is placed outside the mold 131.

The cooling body cooling mechanism 231 comprises a flexible piping 232 having one terminal connected to one of the pipes 222 and the other terminal connected to the other pipe 222 and communicating with the flow path formed inside the cooling body 211, a refrigerant storing part 233 disposed halfway along the length of the piping 232, a refrigerant cooling part 234 disposed halfway along the length of the piping 232 and adapted to cool the refrigerant, and a pump 235 disposed halfway along the length of the piping 232 and adapted to circulate the refrigerant.

Now, the production of the ingot N will be described below. Since it is nearly wholly identical with that of the second embodiment, only the portions different from those of the second embodiment will be described.

In the second embodiment illustrated in Fig. 4 and Fig. 5, when the mold 131 is conveyed and stopped at the molten metal supplying position (vibrating position) (Pa), the cooling body moving driving part (224) not shown is actuated to insert the cooling body 211 into the mold 131, position it at the cooling body moving position (descended position) and set the vibrating part 223 into motion.

Then, by driving and descending the heater-embedded control bar (122) with the control bar driving part (123), the molten metal M is enabled to be delivered in a prescribed amount from the delivery tube (113) into the mold 131.

The molten metal M which has been delivered in the prescribed amount into the main body of the mold (132) as described above is poured onto the cooling body 211 and cooled by contacting the surface of the cooling body 211 kept cooled with the cooling body cooling mechanism 231 and consequently crystallized and spheroidized and caused to adhere to the surface of the cooling body 211.

Since the cooling body 211 is vibrated with the cooling body vibrating mechanism 221, the spherical crystals while in the process of growing are forcibly liberated from the surface of the cooling body 211 and dropped into the main body 132 of the mold.

Then, the molten metal M which has fallen into the main body 132 of the mold is cooled by contacting the inner surface of the main body 132 of the mold and consequently grown into spherical crystals and allowed to adhere to the inner surface of the main body 132 of the mold.

After the mold 131 placed at the molten metal supplying position (vibrating position) (Pa) has been vibrated for a prescribed duration such as, for example, approximately in the range of one minute to five minutes as described above, the vibrating part 223 is stopped and the cooling body moving driving part (224) not shown is actuated to place the cooling body 211 at the non-vibrating position (ascended position).

The subsequent steps are similar to those of the second embodiment.

According to the ingot producing device P of the third embodiment of this invention, since the cooling body 211 itself is capable of cooling the molten metal M and the cooling body 211 is provided thereon with the cooling body vibrating mechanism 221 for the purpose of preventing the molten metal M from being solidified on the cooling body 211 and forcibly liberating and flowing down the crystals formed on the surface of the cooling body during the initial state of formation thereof, the ingot N of the solid phase comprising fine spherical crystals can be efficiently produced without enlarging the device in use as compared with the conventional device of mechanical stirring or electromagnetic stirring and without increasing the cost of energy.

Owing to the provision of the cooling body cooling mechanism 231 for the purpose of cooling the cooling body 211, the cooling body 211 can be retained at a constant temperature and the ingot N of the solid phase comprising fine spherical crystals can be produced efficiently.

Fig. 9 is an explanatory diagram equivalent to a lateral cross section schematically illustrating another example of the melting furnace to be used in the continuous cast bar producing device or the ingot producing device.

Referring to Fig. 9, the melting furnace 11, 111 comprises a main body 12, 112 of the melting furnace opened in the upper part, a crucible 12A, 112A removably contained as an internal vessel in the main body 12, 112 of the melting furnace, a delivery tube 13, 113 mounted with water tightness as transfixed through the bottom of the main body 12, 112 of the melting furnace and enabled to transfix removably the bottom of the main body 12, 112 of the melting furnace and allow the upper terminal thereof to reach the prescribed position in the crucible 12A, 112A, a heater 14, 114 embedded in the main body 12, 112 of the melting furnace, and a lid 15, 115 for blocking the upper part of the main body 12, 112 of the melting furnace.

Then, the melting furnace temperature adjusting mechanism 17, 117 comprises a thermocouple 18, 118 as a temperature measuring device for measuring the temperature in the melting furnace 11, 111 and an electrification controlling part 19, 119 for starting supply of electric power to the heater 14, 114 for enabling the temperature detected by the thermocouple 18, 118 to reach the prescribed melting temperature and stopping the supply of the electric power to the heater 14, 114.

Incidentally, the temperature of the interior of the melting furnace 11, 111 is set by the melting furnace temperature adjusting mechanism 17, 117 at a level not lower than the liquidus temperature of the magnesium alloy so as to produce the molten metal M of a magnesium alloy.

The molten metal delivery controlling mechanism 21, 121 comprises a heater-embedded control bar 22, 122 inserted through the insertion hole 15a, 115a formed in the lid 15, 115 of the melting furnace 11, 111 and control bar driving part 23, 123 for inserting the heater-embedded control bar 22, 22 into the melting furnace 11, 11 and consequently

expelling the molten metal M through the delivery tube 13, 113.

Now, the melting furnace 11, 111 will be described below.

The melting furnace 11, 111 is not provided with a dross vent. When they retain only small amounts of molten metal M and dross after they have delivered the prescribed amounts of the molten metal M, the lid is opened to remove the crucible 12A, 112A from the interior of the main body 12, 112 of the melting furnace and a new crucible 12A, 112A is contained in the main body7 12, 112 of the melting furnace as illustrated in Fig. 9.

Then, by charging the crucible 12A, 112A with necessary metals, closing the main body 12, 112 of the melting furnace with the lid 15, 115, and heating the main body 112 of the melting furnace with the heater 114, thereby melting the metals, the molten metal M of a magnesium alloy can be formed.

Thereafter, the molten metal M is successively delivered in the prescribed amount by manipulating the molten metal delivery controlling mechanism 21 and 121 in the same manner as already described.

The melting furnace 11, 111 is provided with a crucible 12A, 112A in place of a dross vent. By replacing the crucible 12A, 112A, therefore, they are enabled to produce the molten metal M anew faster than the procedure of newly forming the molten metal M by discharging the dross via the dross vent.

As a result, the melting furnace is capable of producing the metal slurry U or the ingot N more efficiently.

When the crucible 12A, 112A removed from the interior of the main body of the melting furnace 12, 112 is made to contain cold water therein, the dross can be set by aging and removed.

The crucible 12A, 112A which has the dross set and removed as described above, therefore, can be prepared for the next service by having the inner peripheral surface thereof cleaned.

In the preceding embodiment, the molten metal M of the magnesium alloy to be handled is liable to undergo oxidation, it is preferred to be handled in an incombustible atmosphere such as, for example, the argon gas or the mixture of sulfur hexafluoride (SF_6) gas with carbon dioxide gas.

While the molten metal M has been described by citing the case of forming the molten metal of a magnesium alloy, it goes without saying that this invention can be applied to aluminum alloys and other metals.

While the first embodiment has been described by citing the case of manufacturing a continuous cast bar B and billets L, this invention can be applied to the production of a plate using the metal slurry U.

By providing the first embodiment with the cooling body 211 and the cooling body vibrating mechanism 221 (and further the cooling body cooling mechanism 231) of the third embodiment in the place of the tilted cooling body 31 and the tilted cooling body vibrating mechanism 36 or providing the cooling body 211 and the cooling body vibrating mechanism 221 (and further the cooling body cooling mechanism 231) of the third embodiment and causing the molten metal M from the tilted cooling body 31 to pour into the cooling body 211, it is made possible to obtain the same effect as in the first embodiment or the third embodiment.

In this case, the cooling body vibrating mechanism 221 does not need to be moved as in the third embodiment.

While the second embodiment and the third embodiment have been described by citing the case of producing a cylindrical ingot N, the casting (ingot) can be directly produced by performing the casting as aimed at producing a casting.

By providing the second embodiment with the cooling body 211 and the cooling body vibrating mechanism 221 (and further the cooling body cooling mechanism 231) of the third embodiment and causing the molten metal M from the cooling body 211 into the mold 131, it is made possible to obtain the same effect as in the third embodiment.

The third embodiment has the effect thereof unimpaired by omitting the cooling body cooling mechanism 211.

Industrial Applicability:

The production of the metal slurry contemplated by this invention comprises pouring the molten metal into the tilted cooling body and cooling this molten metal on the tilted cooling body and meanwhile imparting vibration to the tilted cooling body, thereby forcibly liberating and flowing down the crystals being formed in the course of cooling.

Thus, it enables the metal slurry possessing fine spherical crystals to be efficiently and continuously produced.

It is, therefore, capable of producing the metal slurry easily even from an Mg alloy which has a small solidifying latent heat and is liable to solidify. Owing to the impartation of the vibration in this case, the time required for the spherical crystals to be liberated from the cooling body can be shortened and the produced crystal grains enjoy enhanced fineness.

Further, since the mold used for producing the ingot contemplated by this invention is provided with the cooling body vibrating mechanism, the produced metal is enabled to acquire a minute spherical structure excelling in mechanical properties.